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EDITORIAL NOTES.

THE whole of the rocks and rock-slices collected by the late Sir Jethro Teall have been generously presented by Lady Teall to the Sedgwick Museum at Cambridge, in recognition of his warm attachment to his old University. In addition to many miscellaneous specimens of interest, this gift embraces all the material of Sir Jethro's published works prior to his joining the Geological Survey in 1888. It is gratifying that so valuable a collection, including the rocks described and figured in the classic *British Petrography*, finds a home where it will be duly appreciated, and will be accessible to workers in petrology. Following upon the recent transference of Dr. Bonney's collections to the same Museum, Lady Teall's liberal act points an example which may be commended to others.

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OWING to pressure on our space it is a long time since there have been any Editorial Notes in the GEOLOGICAL MAGAZINE, but the Editor wishes on this occasion to point out to contributors two ways in which they can facilitate his work. In the first place, as regards orders for separate copies of papers, an immense amount of trouble and unnecessary correspondence would be saved if the order-form for such copies, as sent with proofs, were always returned *to the Editor*, instead of to the printers, as is sometimes done. Further, if no separates are required the form should be returned blank or cancelled. These points have been mentioned before in these Notes, but without result. Secondly, the Editor would ask his kind contributors to refrain from sending in heavy and bulky manuscripts at the recognized holiday seasons, that is in Christmas week, Easter week, and from 15th August to 1st October. At such seasons the Editor is always away from Cambridge, and parcels, if received there, have to be forwarded, with further risk of loss in the double transit; moreover (a purely selfish consideration) such parcels make an unnecessary addition to the bulk of the Editor's luggage when he returns to Cambridge. These are examples of the minor difficulties that attend the conduct of a periodical that has no office and no staff.

ORIGINAL ARTICLES.

Isostatic Tendencies as the Origin of all Geodynamic Phenomena.

By C. G. S. Sandberg, Sc.D.

C. E. DUTTON, in his paper on some of the greater problems of physical Geology (*Bull. Phil. Soc. Washington*, vol. xi, pp. 51–64, 1889–91), formulated his conception of *Isostasy* in the following words: "For this condition of equilibrium of figure to which gravitation tends to reduce a planetary body, irrespective of whether it be homogeneous or not, I propose the name of *Isostasy*. Isostasy is being disturbed by denudation and sedimentation . . ."

It is evident from the above that Dutton only considered one form of tendency to equilibrium, namely the one initiated by differences of weight. Yet this tendency to equilibrium is universally inherent in difference, irrespective of the nature of such difference, and of the matter involved.

Atmospheric and oceanic circulations, atmospheric absorption and precipitation, with rain and rivers, lakes and oceans, ground-water circulation, ebb and flood, are so many manifestations of these energies, fundamentally identical with the vital functional circulations of plant and animal life, and all other physical and chemical reactions. Their duration is tied down to that of the matter and the source of energies concerned, and their manifestations constitute systems closed in themselves, yet mutually interacting and antagonistic.

These tendencies being secular and universal, in fact, cosmic, it would seem that for a solution of the geodynamic problems of our lithosphere we shall have to consider the isostasy problem from a broader basis, as Dutton did and as is being done generally.

No proffered solution can, however, aspire to any merit unless it constitutes a closed system, a cycle in itself as well as in its consequent deductions, as we see realized through the whole length of geological history.

I therefore would propose a broader definition of the term Isostasy, and formulate it in the following words: for this equilibrium of status to which difference tends to reduce matter, irrespective of whether it be homogeneous or not, I propose the name of Isostasy. Isostasy is being disturbed by various causes (energies).

This tendency to isostasy which, if (more or less) realized in one sense, provokes differences in another, is at the bottom of all geodynamic movements and tendencies to movement. In studying the problems of physical geology it is therefore incumbent on us not only to consider the effects of the universal tendency to *gravitative isostasy* but also those produced (or likely to be produced) by other causes. Thus the differences in rotatory speed (Wegener), level and

weight (Dutton), temperature, elasticity, and mobility between the different parts of our globe, which all combined and separately will provoke tendencies towards isostasy, should be examined upon their share of impulse towards any given geodynamical manifestation, that is, towards any inclination to establish some form of isostasy, which if realized generally constitutes a disturbance of some other form of equilibrium simultaneously.

Meanwhile, it should be remarked here, and always remembered, that the realization of such tendencies is attended with a certain (more or less) retardation between cause and effect, and with an over-accumulation of potentialities, which latter will cause the ultimate effect to overpass the true status of equilibrium in a way similar to that of a swinging pendulum.

It is clear that the full and total realization of the isostatic status means either absence of potential or dynamic differences or equilibrium between these differences. We will now come back to the study of the initial causes of geodynamic manifestations (Isostasy-disturbing forces).

The isostatic differences liable to be caused by differences in rotatory speed and by the attraction of the planetary system outside our globe, on our semi-rigid planet, are of such a nature that their supposed effects cannot be brought home with any degree of certainty as yet to these causes, excepting with regard to the extremely mobile fluids of hydrosphere and atmosphere.

As it is our intention to study the causes of those geodynamic manifestations of our lithosphere, the effects of which, be they past or contemporaneous, are measurable without any doubt, we will leave the above-mentioned causes of probable isostasy-disturbing energies undiscussed.

And as the geodynamic manifestations of our lithosphere are the result of the interactions of energies prevailing above and beneath its surface as well as in its body, we will first of all briefly recall the nature and origin of these energies above it, i.e. in the hydrosphere and atmosphere.

It is generally admitted that as a result of unequal solar heating systems of movements are engendered in the atmosphere and the hydrosphere which in themselves are closed. They are the great constant cyclic movements of hydrosphere and atmosphere ever kept alive and vitalized by differences of temperature and density and by their mutual interaction.

Remembering this, we may formulate our first conclusion, namely :—

I. Unequal (solar) heating engenders systems of isostatic movements which in themselves are closed in the hydrosphere and atmosphere, Isostasy being constantly disturbed by differential (solar) heating at the surface of the lithosphere (thermal isostasy-disturbances).

It is also generally known, however, that the above effect is being

realized only because air and water, like all matter, undergo a change of density under the influence of augmentation or abstraction of heat. The hotter, lighter air or water ascending, the colder, heavier air and water descending, that is to say, their *gravitative* isostatic state is being disturbed by unequal solar heating. We may thus formulate our second conclusion, namely :—

II. Unequal (solar) heating disturbs gravitative isostasy in the hydrosphere and atmosphere engendering a closed system (cyclus) of movements in them (gravitative isostasy-disturbances).

From conclusions (1) and (2) we derive the final conclusion, namely :—

III. Unequal (solar) heating engenders disturbance of thermal and gravitative isostasy and thereby creates systems of compensatory (isostatic) movements, which in themselves are closed.

All these isostatic disturbances and their consequent movements are of a physical nature. Yet another isostatic movement on the surface of our lithosphere is engendered by unequal (solar) heating. We are alluding to the varying power of absorption and precipitation of water vapour by the atmosphere under the influence of unequal or variable heating. We arrive here at the transitional stages between physical and chemical isostasy, the disturbances of which, in the form of erosion and subsequent denudation and sedimentation, play such an important part in engendering geodynamic manifestations.

We are thus led to our fourth conclusion, namely :—

IV. Unequal (variable) (solar) heating engenders not only physical but also chemical isostatic disturbances (in atmosphere and lithosphere), creating systems of movement which in themselves are closed (cycli). Of the isostasy-disturbing sources considered above, the one, heat, is external (solar), the others are internal (physical : e.g., gravitation ; chemical : e.g., molecular affinity-tensions). Practically we may take them as constant and their effects will last as long as the sources and the subject matter last.

It should be mentioned that yet another source of isostatic disturbances exerts its influence on hydrosphere and atmosphere, a source which is equally cosmic, external, namely the cosmic attraction, causing another system of movements (ebb and flood), which in itself is also closed. As remarked above, we will not here consider these energies or their supposed effects.

Consequences of the Isostatic Cyclic Movements above and at the Periphery of the Lithosphere.

The consequences of these isostasy-disturbing energies, resulting in cyclic movements, manifest themselves above and in the upper regions of the lithosphere.

Before considering the isostasy-disturbing sources which may be seated beneath our lithosphere and their possible causal influence on geodynamic manifestations, we will briefly summarize and consider the consequences of the cyclic disturbances formulated above,

which find their impulse in denudation and sedimentation. We repeat that Dutton, in saying "isostasy is being disturbed by denudation and sedimentation", was only considering that form of isostasy which I named "gravitative" isostasy (Sandberg, *Geodynamische Probleme*, I, Gebr. Borntraeger, Berlin, 1924).

Hence his conclusion that "(on the contrary) the very idea of isostasy means the conservation of profiles against lowering by denudation on land and by deposition on the sea-bottom".

Dutton evidently only considered that denudation lightened certain parts of our lithosphere, while subsequent sedimentation weighted down other parts, thus disturbing gravitative isostasy.

Below we shall see that these processes disturb yet another form of isostasy, a form which I named *thermic* isostasy (Sandberg, loc. cit.).

Admitting for the moment a sufficient plasticity (or semi-rigidity) of planetary matter beneath our lithosphere, generally called magma, a necessary assumption for the adherents of the prevalent Duttonian isostasy theory, we must emphasize here that denudation and sedimentation, while *disturbing* one form of (gravitative) isostasy, like all other geodynamic functions, simultaneously tend towards *establishing* another form of isostasy (of level).

A. Born (*Isostasie und Schweremessung*, Berlin, Jul. Springer, 1923) independently, and arguing on a different basis, arrives at the same conclusion as we did before him. Admitting that the material removed by denudation from one part of the surface of our lithosphere will provoke tendencies to isostatic movements, which, *when realized*, will cause such part to move in a centrifugal direction, he rightly points out that this compensatory movement can never restore the surface of such part to its former level. Neither can the weight of the material deposited by sedimentation cause the part of the lithosphere concerned to move in a centripetal direction until its new surface occupies the same level as the old one did. In the one case (denudation) the lighter surface material is being *replaced* during the process of compensation by the heavier (denser); in the other (sedimentation) it must *displace* such heavier (denser) magmatic matter. The new surfaces consequently will occupy levels which compared to the old ones stand in a ratio inversely proportional to the densities of the removed and supplanted matter.

Denudation and sedimentation would consequently tend to abolish one source of isostatic movements, namely, that which is connected with differences of level on the surface of our lithosphere.

Should no reviving energies exist, its ultimate effects would therefore be identical irrespective of an assumed magmatic plasticity (semi-rigidity) sufficient to allow these compensatory movements or not. We shall therefore have to look for other energy or energies capable of ever reviving these differences. Prevalent conceptions place this source of energy in the secular contraction of our globe, subsequent to its cooling. Its theory is known as the *contraction*

theory, which is supposed to account for some geodynamic manifestations.

In briefly discussing the merits of this theory it should be remarked at the outset that *it has no foundation whatever in observed facts, as there is no matter known, be it an element, alloy, mixture, or chemical compound, which through contraction, subsequent to slow cooling, causes its solidified envelope to wrinkle or fold.* Its validity, therefore, becomes very problematic. As far as our earth's envelope is concerned, it seems possible to be more precise still in our refutation of the validity of the contraction theory inasmuch as it pretends to give a reasonable basis for the explanation of the orogenetic problem.

This envelope, our lithosphere, is on the basis of this very theory, the product of solidification of our once liquid globe. It consists (be it partly now in the modified form of sedimentary rock) of solidified magmatic rock, such as we find to-day extended at the surface over vast areas, denuded of its erstwhile sedimentary cover, in anticlinal folds of mountain ranges, in laccoliths, sills, and dykes, and other forms. Yet no folding of its surface nor of its cover, *as a result of its contraction* subsequent on cooling, could ever be registered.

Besides, the theory is in poignant contradiction with the assumptions, equally prevalent, conceived to explain a characteristic, typical of orogenetic manifestations, namely, its localization to regions of sedimentation ; I am alluding to the assumption according to which all rocks are supposed to become plastic under the influence of (sufficient) pressure *alone*.

Volcanism and orogeny, although manifestly inseparably connected in time and space through the whole of geological history, cannot be causally related, much less identified in origin on the basis of the contraction theory.

These and other facts condemn the contraction theory when tested on its own merits, as I pointed out recently in my *Geodynamische Probleme*, II (Borntraeger, 1924).

A theory which has no foundation in observed facts, and which moreover is in perpetual contradiction with both its own logical deductions and the assumptions necessary to explain observed geodynamical manifestations, cannot longer be maintained as a reasonable basis to work upon, and must therefore be abandoned. We have to look for another source or sources of energy.

Other sources of Isostasy-disturbing Energies.

Besides the sources of energy above mentioned tending to produce tensions, and hence complexes of movements disturbing and restoring isostasy, there is yet another capable of causing powerful geodynamical manifestations, which we will consider. It is the internal heat of our planet.

We may leave the question of the origin of this internal heat

undiscussed here. For whether we place its source in the supposed unsolidified remnant, the nucleus of a once entirely liquid globe (contraction theory, Kant-Laplace, Lord Kelvin, Chamberlin, etc.), or whether we look upon it as the result of chemical and physical reactions, or as originating from both these sources and their interaction, is of no consequence to our argument. Sufficient is the acknowledgment of its presence to which we are forced theoretically as well as by the variety of its manifestations.

One of its most striking manifestations, because of its magnitude and its contemporaneousness with mankind, is volcanism. Besides being inseparably connected with the *internal heat of our globe, volcanism is also inseparably connected*, as we remarked above, in time and space *with orogenetic manifestations*, mountains and mountain ranges.

From these conclusions it would not seem hazardous to derive another, namely, that there should exist some *inseparable, perhaps causal connexion between internal heat and orogeny.*

And as orogenetic manifestations are locally restricted to sedimentation, yet another conclusion seems to accrue, namely, that there should exist an *inseparable connexion between internal heat, orogeny, and sedimentation and denudation.* From my *Geodynamische Probleme* I, above cited, where I treated this question in detail, I summarize here the following.

We will consider two adjoining sections of our lithosphere, the crust, respectively named G.A. (=geoanticline) and G.S. (=geosyncline), at the moment that they are in gravitative and thermal isostasy. With respect to the latter condition, this means that the temperature differences between the source of heat M (=magma) and the surfaces of the G.A. and the G.S. are equal. Moreover, for both we have the general equation :

$$W = W'$$

meaning that the heat passing at the surfaces of the G.A. and the G.S. per unit of time and surface is equal to the heat simultaneously supplied (thermal isostasy). For each region separately we may express these values as :

$$Wga = W'ga \text{ and } Wgs = W'gs.$$

Now W, in Wga and Wgs, is directly proportional to temperature difference and thermal conductivity (*which we will take as constant*) and inversely proportional to the respective radial distances from the source of heat to the points considered. In our case we will consider the thicknesses of the crust, which we will call respectively Δga for the geoanticline and Δgs for the geosyncline. Now supposing denudation to have set in after the moment of isostasy considered above, resulting in the removal of an amount of rock from the G.A.'s surface of a thickness say Q.

The thickness of the crust will thereby be reduced to the proportion of

$$\Delta ga - Q$$

and as Wga is inversely proportional to the thickness of the crust, the result will be :

$$Wga > W'ga$$

We may thus formulate our fifth conclusion, namely :

V. *Denudation disturbs thermal isostasy in the geoanticline.*

Simultaneously sedimentation has been going on in the G.S. region, depositing on its original surface an amount of denudation products of a thickness say =X, and bringing the total thickness of the crust there to

$$\Delta gs + X$$

Wgs being inversely proportional to the thickness of the crust, the result will be

$$Wgs < W'gs$$

which may be formulated in our sixth conclusion, namely :

VI. *Sedimentation disturbs thermal isostasy in the geosyncline.*

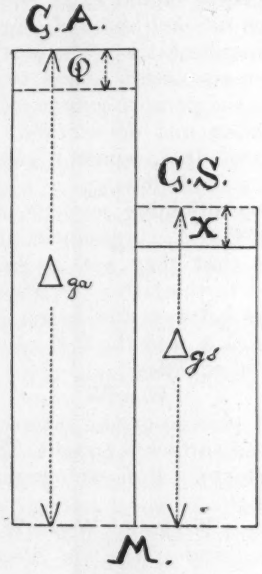

FIG. 1.

We will now trace briefly, the further consequences, if any, of these isostasy-disturbing energies referring for details to our above-cited publication, and see if their interaction can possibly lead to a system of cyclic movements of our lithosphere, ever revived by the action of the internal source of heat *and, if so, whether their manifestations, if any, will be restricted to those regions where they actually occur at the surface of our globe.* For that purpose let us consider a unit of surface M, at the very boundary between solid and (latent) liquid rock under the surface of the G.A. Its condition of thermal isostasy

we are considering may be represented, as before, by the equation

$$Wga = W'ga$$

which means that no liquefaction of the solid and no solidification of the (latent) liquid rock takes place in any direction. Equilibrium reigns. Now denudation sets in, removing from the surface of the G.A. a layer of a thickness say Q, and causing at the newly acquired surface Wga (heat emitted) to become greater than W'ga (heat supplied) pro unit of surface and time Thermal conductivity will, after some time, transmit this difference to the surface M we are considering, and beyond.

The consequence will be a solidification of the (latent) liquid rock to an extent corresponding with the melting heat of exactly

$$Wga - W'ga.$$

So if the heat of fusion per unit of mass be S, a mass $\frac{Wga - W'ga}{S}$ will solidify per unit of time and surface at the lower surface M of the G.A. The increase of thickness will be given by

$$\frac{Wga - W'ga}{\rho S}$$

if ρ is the density of the solid material.

Should equilibrium continue to be disturbed during a length of time, *t*, in the same proportions, then the increase would attain a thickness per unit of surface equal to :

$$\frac{(Wga - W'ga) \cdot t}{\rho S}$$

VII. *We thus see that denudation of the G.A. causes decrease of thickness at its surface, which is (with some retardation) compensated by an increase through solidification at its lower boundary between solid and (latent) liquid rock (magma)*, until isostasy, i.e. Wga=W'ga, shall be restored again. At that moment the total thickness of the G.A. crust will correspond to the equation :

$$\Delta'ga = \Delta ga - Q + \frac{Wga - W'ga}{\rho S} \cdot t$$

in which Δga and $\Delta'ga$ stand for the original and new thickness of the solid rock of the G.A. respectively.

Let us now consider the effects of sedimentation in the G.S. Before it started we supposed the G.S. to be in thermal isostasy at its surface, consequently (Fig. 2)

$$Wgs = W'gs$$

meaning Wgs=heat emitted being equal to W'gs=heat supplied.

At the boundary surface between solid and (latent) liquid rock M' no liquefaction nor solidification of the magma takes place.

We have seen above that after sedimentation has commenced

$$Wgs < W'gs$$

i.e. that Wgs = heat emitted has become smaller than W'gs=heat supplied at the surface. Thermal conductivity will here again, with some retardation, transmit this difference from the surface to the boundary of (latent) liquid and solid rock M.

The consequence of this excess of heat supply will be a (latent) liquefaction of the solid rock at M and above it, corresponding with the melting heat of exactly

$$W'gs - Wgs$$

per unit of time and surface.

Be the heat of fusion per unit of time and mass=S′ than a mass $= \frac{W'gs - Wgs}{\rho S'}$ will be liquefied, if ρ be the density of the solid rock.

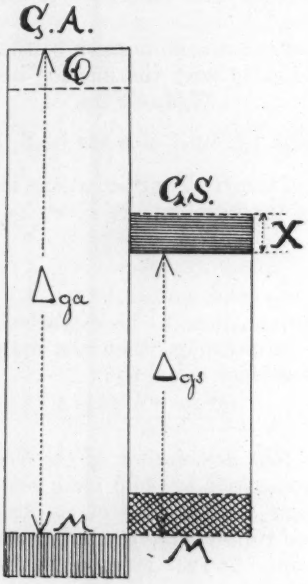

FIG. 2.

Thicknesses: denuded from G.A. / sedimented on G.S.

Thicknesses: solidified under G.A. / liquefied under G.S.

During a time t a thickness will be liquefied per unit of surface equal to

$$\frac{(W'gs - Wgs) \cdot t}{\rho S'}$$

VIII. We thus see that sedimentation on the surface of the G.S. causes increase of the *thickness of the solid crust at the surface, which will be compensated (with some retardation) by a decrease through liquefaction at its lower boundary between (latent) liquid and solid rock*, until isostasy, i.e. Wgs = W′gs, shall have been restored.

At such moment the total thickness of the solid G.S. crust will correspond to the equation

$$\Delta'gs = X + \Delta gs - \frac{W'gs - Wgs}{\rho S'} . t$$

in which Δgs and $\Delta'gs$ stand respectively for the original and the new thickness of the solid crust of the geosyncline.

Should, in the above equation, $\frac{W'gs - Wgs}{\rho S'} \cdot t$ ultimately become $=> \Delta gs$, we would have

$$\Delta'gs = X \text{ and } \Delta'gs < X$$

meaning, as our ninth conclusion, that:

IX. *Accumulation of sedimentary deposits in the G.S. tends to liquefy the originally supporting solid rock,*[1] *the crust in the G.S. ultimately causing not only its total liquefaction, but even that of the deeper parts of those sedimentary deposits.*

By consistent and critical deduction of the consequences evolving from our original premise, we have consequently arrived at a natural and plausible explanation of a phenomenon, observed all over our globe, namely, that basal parts of sedimentary deposits have evidently been in contact with, melted and absorbed to a lesser or greater extent by, the magma, a fact the *modus nascendi* of which hitherto lacked a satisfactory explanation.

Yet still more inevitably follows from our above-cited conclusions, more particularly from the one last formulated, as it should be remembered, and ever retained, that:

(*a*) These sediments were (and are) deposited in (ocean) water-covered regions.

(*b*) The capillary spaces between the solid particles (pore space) of these sediments must therefore have been filled by this liquid.

(*c*) Pore space constitutes from 10 to 35 per cent and more of sedimentary rock-volume (F. H. King, "Principles and Conditions of Movements of Groundwater," 19*th Ann. Rept. U.S. Geol. Surv.* ii, 1897–8). It is clear that when these sedimentary deposits, laden still were it only with part of their water content, could reach the zone of liquefaction, expanding vapour tensions would be engendered sufficient to raise the overlying sedimentary material from their ocean-covered levels to such of our highest mountain ranges and (or) manifest themselves in volcanic emanations with their characteristic accompaniments of vapours and gases (violent eruptions, fumeroles, mineralization, and such like).[2]

[1] The words "solid" and liquid (or latent-liquid) are here used comparatively. The physical state of the liquid or latently liquid rock or magma may be left undiscussed here. See our *Geodynamische Probleme*, Berlin, 1924, I and II.

[2] It seems appropriate to mention here that T. Mellard Reade calculated that the mere transition of rock from the solid to the liquid state in geosynclinal regions, consequent upon the piling up of sedimentary deposits in the G.S., would entail such expansion as sufficiently to account for the production of mountain-ranges. (T. Mellard Reade, *The Evolution of Earth Structure*, 1903, Longmans, Green, & Co., New York and London.)

I elaborately exposed in my *Geodynamische Probleme* I, that we are entitled to the almost certain conclusion that these capillary water contents were still occupying the pore spaces of sedimentary rock when it reached the zone of liquefaction, in spite of the high vapour tensions bound to prevail in these regions, consequent upon the high temperatures reigning there.

Sufficient be it to recall here that the question ultimately may be reduced to the following :—

Is it probable that the overlying sedimentary strata would prevent the escape of such enormous vapour tensions until their potential energies ever accumulating, could be transformed into kinetic energies upheaving the overlying strata ; will they not have escaped already, long before such tensions could have been realized ?

Putting the question means answering it. For it is clear that whatever our conceptions about the origin of volcanism may be, its substance is a thermo-dynamic problem, which consists mainly in finding a satisfactory solution for the origin of heat and of the enormous vapour tensions, which are both inherent to volcanism, no matter in what way it expresses itself.

And it is equally clear that before these vapour tensions could come to such an expression they were being prevented from escaping by their sedimentary cover until their potential energies had accumulated to such dimensions that they could become kinetic and, lifting or forcibly piercing their envelope, manifest themselves in laccoliths, sills, dykes, and such like magmatic structures, or in gigantic volcanic outbursts.

In studying those magmatic structures more closely, as they are described and designed by various authors (G. K. Gilbert, W. H. Weed, and L. V. Pirsson in America, V. de Derries in the Kaukasus, E. Kaiser in South Africa, etc.), it even becomes a matter of surprise to note how thin, comparatively, these sedimentary covers actually were, when still they could prevent the high-tension gases and vapours from escaping, thereby enabling the magmatic structures to develop to such enormous dimensions as we find them to-day in various parts of the earth.

Our tenth conclusion may consequently be formulated—

X. *The vapour tensions engendered under our solid lithosphere can be kept bound by covering sedimentary deposits until their accumulated potential energies have acquired dimensions large enough to raise or explode their overburdening envelope*; and as we demonstrated above, that these energies will be engendered in the geosynclinals of our globe exclusively, we may further formulate our final conclusion—

XI. *Sedimentation in the geosynclinal, through its interaction with the internal heat of the earth, tends to engender orogenetic energies which when realized may re-establish the isostatic differences (differences of level) which in interaction with denudation and gravitation it was tending to abolish.*

Our deductions, consequently and naturally, evolved to the cycle : XII. Denudation — gravitation — sedimentation — orogeny— denudation—and so forth, being ever revived by the internal heat of the earth ; this cycle, moreover, evolutionizing only in the very regions empirically established to be the exclusive seat of its evolution.

Geology in the Service of Man.[1]

By Professor W. W. Watts, Sc.D., LL.D., F.G.S., F.R.S.,
President of the Section.

Introduction.

IT was hoped that this section would have been presided over by Dr. C. W. Andrews. He had, indeed, accepted the invitation of the Council to become President, but the state of his health later compelled him to resign. His untimely death has deprived our science of a widely travelled and most talented geologist and a vertebrate palaeontologist of world-wide distinction.

Although Geology in the modern restricted sense of the word is over a century old, and possesses a flourishing family of descendant sciences, it is still possible to trace its immediate parentage and ancestry. The only begetter is unquestionably the mining industry, and it is to the ample exposure of rocks in mines, their condition and arrangement in the simpler mining districts, and the necessity for accurate knowledge of these districts with regard to composition, succession, and arrangement, that we owe the earliest detailed knowledge of the earth-crust in certain restricted localities.

The other parent was of more advanced years, and may be described as "insatiate curiosity"; the natural instinct for observing and collecting odd and bizarre "rarities" found in excavations or seen in natural rock exposures. These fossils, using the word as then employed and not in the restricted sense now usual, naturally kindled interest by reason of their natural beauty, their regularity in shape, their properties, their likeness to, and yet their tantalizing difference from, the appearance of living animals and plants. It was tempting to draw inferences from their occurrence and to explain them either by marvellous operations which fuller understanding of Nature had not then inhibited, or by means of catastrophic events like those familiar in the Mosaic cosmogony.

Although much had been observed and thought out by his predecessors, it is to Werner that we owe the most successful generalisations in a mineral-bearing district; generalisations which gained a wide influence owing to the enthusiasm and eloquence

[1] An address delivered before Section C (Geology) of the British Association at Toronto, 1924.

that attracted students from all over the world and imbued them with the desire to confirm and spread the Master's ideas. To Werner also is due a reaction from the fanciful speculations of preceding periods with which he was so impatient that he proposed to drop the very term Geology and to substitute his own word " Geognosy " for it, a word intended by him to separate the knowable from the unknown.

Probably there would have been less controversy between Neptunists and Plutonists had Werner committed more of his work to writing, and not left us dependent on his pupils for their versions of his views. But it is a curious fact, and one probably not dissociated from a geologist's devotion to field study, that many of those who have made great advances have either disliked the act of writing or have been unfortunate in the style of their written work. It will be sufficient to couple with Werner in this respect such names as William Smith, Sedgwick, and even Hutton, not to mention those of more recent geologists. It has not been from Smith alone that views and conclusions have had to be extracted, almost by force, and committed to writing by faithful devotees.

Yet, after all, this failing has not been without its advantages. The joy of such men is in discovery, and they are happy and contented when, but only when, they feel perfect confidence in their conclusions. If their results then get published it is with an authority and finality denied to lesser men. In the progress of their work they are apt, as in fact all of them did, to infect their friends and students with the enthusiasm that only the spoken word can arouse. And to others they have always been most generous, even lavish, in giving ideas and momentum, partly out of sheer good nature, but much more through the desire to watch the germination of the good seed that they sow broadcast and to see the harvest reaped, not by or for themselves, but for the advantage of the science whose welfare is their chief care.

During the early growth of the science, as in human families, it was the influence of the other parent that was most felt. From the earliest thinkers of Greece and Rome we have record of numberless observations and discoveries, sometimes in respect of minerals or organic fossils, sometimes of unusual phenomena in mountains or volcanoes or in the relations of sea and land, generally leading to reasoned conclusions, many of them perhaps fanciful, some even absurd, but others so sound and far-seeing that they have not been upset at the present day. Many other countries, joining the favoured ones along the Mediterranean, carried the torch forward, and in spite of the clogging influence of the vested intellectual interests of the day, the stock of knowledge gradually grew, until we find that Leonardo da Vinci was able to make as great an advance in the knowledge of the earth as he did in his own arts of painting, sculpture, and architecture.

It is true that during this period observers had a tendency to

confine themselves too exclusively to one or other side of their subject, and were in the habit of reproaching one another with neglect of neighbouring branches, but even this made for progress by stimulating competition and discussion.

In spite, however, of all that had gone before in the fields both of fact-collecting and of speculation, it will be admitted that no single man made so great an individual advance, or placed it upon such an enduring foundation, or did so much on which the future of his science was to depend, as William Smith. And it is noteworthy that the spur to his discoveries was not so much his theoretical views or even his scientific zeal, as a plain and practical issue—the finding of a short cut to speedy and accurate land valuation.

The discovery by the "Father of English Geology" that fossils are the "medals of creation" and that strata are each characterized by special suites of organisms, was certainly one of the greatest ever made in the history of geology, and upon it have been founded, directly or indirectly, almost all the later advances in the science. But for the fuller utilization of his discoveries there were needed the artistic faculty and a wide knowledge of places and people, both of which he fortunately possessed. Thus he was able to introduce handy, crisp, easily remembered and pleasantly sounding local terms to characterize his "Formations", and to represent the outcrop of strata on maps which were not merely topographical but, for the first time, were tectonic also. So well did he discharge this latter function that a comparison of his general map of England with the latest production of the Geological Survey on a scale at all comparable with it fills one with astonishment at the amount of work accomplished by him single-handed, and with admiration for his accuracy.

It is strange that, in the amateur and official work which followed during much of the nineteenth century, so little interest was taken in the industrial application of geological knowledge which, in Smith's hands, had been so productive. The science had, as has been said, the "landed manner", and the dignity of its application to arts and industries was little appreciated. A former Director of the Geological Survey of Great Britain, Sir Andrew Ramsay, quoted with approval the saying of one of his colleagues, "it is but the overflowings of science that enter into and animate industry." And thus, though the scientific side of geology stood to gain much otherwise unattainable information from contact with its economic application, this source of knowledge was not fully utilized, and an air of mutual suspicion—not wholly unjustified—grew up between "theoretical" geologists and those who applied geology to mining and other economic problems. Fortunately this feeling is passing away; the two sides have found that each is indispensable to the other, and geologists are everywhere co-operating with those whose work is connected with the discovery or exploitation of the mineral wealth of the earth-crust.

Material Service.

Coal.—The first branch of industry to which geology made itself indispensable was coal-mining. Geology has long been in close contact with its problems, in mapping the extent of coal-fields, collecting information as to the succession of measures and the existence and lie among them of wants, faults, and igneous rocks, tracing the extension and variation of coal-seams, and estimating the resources available; and, as seams are worked at increasing depths, and in those parts of fields concealed under thick unconformable cover of more recent formations, the work of the geologist has become more essential and increasingly productive.

It is interesting to observe the application of the "academic" sides of geology to these more recondite problems, in unravelling tectonic complexes, in the collection of facts which may eventually elucidate the precise conditions under which different varieties of coal have originated, in applying knowledge as to the limits of the original areas of coal deposit, in the interpretation of stratification in the light of progressive travel of coal-forming conditions geographically across the coal-producing areas, and in the stratigraphical relationship and exact mode of formation of the covering rock-systems.

It is true that the accessibility of coals when first exploited, and their distribution in seams of varying quality, led, and in the newer areas are still leading, to much waste; waste on fruitless search in the light of obtainable knowledge, in exploitation of good, thick, and easily worked seams to the neglect of poorer ones, in the non-preservation of satisfactory plans and the consequent leaving of derelict areas, in unsatisfactory drainage, and in the loss of valuable by-products. But there is a corresponding advantage to those of our generation that some exposed areas of complicated structure, and many of the concealed coal-fields, were left for ourselves and future generations by reason of working difficulties which it would have been premature to face in the time of easily obtained abundance.

Even to-day, in spite of improved technical knowledge, there remain many areas in which information and inference are both scanty, and where difficulties met in working have not yet been surmounted, while there will be in the future ample scope for improved methods and inventions to deal with coal at greater depths than those at which it can at present be economically worked. There is room for much new and more precise study than has yet been devoted to the variation of coal-seams, both in the vertical direction and when traced over the wide areas of their extent. Elaborate and knowledgeable sampling, followed by new means of testing, and these again by new methods for recognition of varieties, have still to be put into practice before it can be said

that we are making a justifiable and economic use of the capital reserves stored up in the rocks.

Oil.—While we blame our forefathers for their destructive and wasteful handling of the coal-fields, it is ourselves and our own generation that we must blame for serious waste of oil and the destructive exploitation of oil-fields that have been permitted. There is no economic subject to which geology has so direct a relation as the occurrence and exploration of oil-fields, and nothing in recent times has given so much employment and such valuable experience to geologists all over the world. It is the only example we have of the sudden introduction of a new source of fuel on a large scale in a late stage of industrial development, and it has already revolutionized many branches of engineering practice. The introduction and spread of the internal-combustion engine and all that this implies in space-economy, cleanliness, labour-saving, and comfort, has been the greatest engineering feature of the late nineteenth and early twentieth centuries, and it has given rise to systems and methods which mankind would be loth to abandon. The whole world is being searched to prolong the good times that we live in ; but in spite of the fact that there probably still remains a recoverable percentage in the oil-producing areas, and that there must be new fields awaiting discovery, there are already signs that the high oil-mark has been reached if not passed. But, again it is no small comfort that although our supply of native oil, easily won and easily refined and applied, cannot last very much longer, there are abundant supplies of oil-shale still left, sufficient to take its place for very many decades to come.

Metals, etc.—Although the greater part of to-day's session is to be taken up by papers and discussions on special sides of economic geology by those who are far more competent than I to speak on them, I cannot resist the temptation to say a few words on that side of the subject which touches on metal-mining. There is probably no subject which has been in the past more dominated by the " practical man ", who may be defined as the most theoretical of all men, but whose theories are seldom proved and are often not susceptible of proof. The valuable information that was accessible to him has been wasted because he could not use it to the best advantage, or else it has been lost because he could or would not impart it. On the other hand, the " theorist ", as he has been contemptuously named, has been hampered because he has often only been called in when difficulties were excessive and when the train of facts or reasoning which would have been so valuable to him has been lost.

In Britain the mining industry is so old and the mineral wealth in certain spots was so plenteous and accessible that the metal-mining geologist has had little chance. The eyes have been picked out of the mines long ago, and in certain cases their very bones picked clean, and the country has been left in such a condition

that its original state can only be guessed at, and problems of relationship, structure, and origin are past solution. Consequently, it is in the countries which have not been inhabited by successive races of highly civilized peoples, or in relation to substances for which there was in the past little or no demand, that the subject has been susceptible of real advance.

Thus it is that such strides in mining geology have been made in Canada, the United States, India, South Africa, and Australia, where there has been a fair field to work upon, and where preliminary surveys have opened up the country and given an idea of its hidden resources. In no other areas of the world has the work of official surveys been watched more carefully by men of capital and enterprise, and money has rarely been lacking for development where there seem to be prospects of a fair return for it. Fortunately, too, the training of official geological surveyors has provided a type of geologist exceptionally well fitted both to prospect independently and to follow out in minute detail, and from a different viewpoint, the preliminary and less detailed examination which is all that is practicable in an official survey. These men have carried with them not merely competence and enthusiasm, but a thorough belief in scientific principles, an extensive knowledge of border-line sciences, and the ability to apply both principles and methods to the problems involved. In the hands of such men the surest guides are scientific principles, just as in the hands of those with "a little learning" imperfectly understood principles are most dangerous; and as the search for ores becomes keener, and as deposits smaller and more tenuous become worth working, the need for increased knowledge of principle and for minute detail in observation steadily grows.

Fortunately, we have not yet exhausted the existing stores of highly concentrated and singularly pure ores, salines, refractories, etc., and the need is less acute than it will become eventually for much improved methods of concentration and purification. When we feel the pinch it will be necessary to call upon the chemist to endeavour to make available the abundant supplies of less pure and less concentrated materials which will remain over for our successors when we have picked out the best. This has already been to some extent effected for oil and it is beginning for coal; it must eventually be done for the still less pure sources of these two substances, for less concentrated ores, and the like.

Stone, etc.—The geologist has already done much in the investigation of the qualities of building stones, plastic substances, and the materials for roofing and cement. To a large extent the materials in use are satisfactory in the air and surroundings in which they occur in Nature. But the added problems of a town atmosphere, accompanied by increased stresses in large buildings and the modern demands of the architect and sculptor, have still to be met, if our buildings are to be more permanent and our towns to present

a less weather-beaten aspect than they now do. New and reliable means of testing are required, and we need a more thorough understanding of the reactions produced by impure atmospheres and the effects of the presence or absence of protective or destructive organisms. Future investigation will react in the production of more satisfactory preservatives, and it may lead to increased production and adoption of artificial stones devoid of the qualities which undermine the power of resistance of natural stones; at the same time more control over colour and shaping may be obtained.

Roads.—Closely akin to the subject of building materials comes that of stones used for flagging, paving, and metalling of roads, to the provision and study of which the geologist has already very largely contributed. New problems are daily introduced as road traffic becomes heavier and as roads are required to be freer from dust and vibration. Already many waste products have come into valuable utilization, and a wide range of road-metals which can be called upon for these purposes exists in almost every country.

In the siting of roads, railways, and canals, however, geology could render much more useful service than it has yet been called upon to give. The routes that are cheapest to make are by no means the cheapest to maintain, and the geological survey of routes would very often suggest slight deviations which would be more economical in the end than when the shortest route compatible with the gradients is taken.

The princes of road-makers in the old world, the Romans, were perhaps too heroic in their dealing with gradients, but they exercised quite remarkable skill in choosing such directions as to secure the least formidable slopes consistent with the general design of their routes. Their roads were, however, constructed primarily for strategic purposes and secondarily for transport, and it was necessary to sacrifice something. On the other hand, the constructors of the coach roads were, perhaps, too sensitive to the psychology of their horses and the limitations of their vehicles, and their roads are not ideal for present-day traffic. Some compromise seems to be required between the two methods, and not the method of the Romans tempered by the cuttings and tunnels of the railway engineer. Now that we have a vehicle that rejoices in the hill, whether for or against it, and for the first time have a means for hill-climbing at speed, it is a pity to flatten down gradients too much; and though it is legitimate and even necessary to remove dangerous crossings and curves, it should be remembered that an everlasting straight vista is as exasperating to a driver as it is heart-breaking to a horse. And if roads of this most desirable type are to be satisfactorily and cheaply maintained, it will be more than ever necessary to study routes in relation to the rocks that are traversed and the water contained in them.

Something of what has been said with reference to roads applies with equal force to other engineering undertakings, railways, and

canals, harbour-works, bridges, and large and heavy buildings, particularly those intended to stand for centuries. The general success of such works is ample testimony to the knowledge and skill expended upon them by engineers and architects, as well as to the elastic toleration of sites so heavily taxed ; and one is tempted to believe that a much larger amount of study has been given to geological questions in these cases than is usually admitted.

Water.—Of all engineering questions, that most closely involved with geological science is probably water-supply. So far as underground water is concerned, geologists and engineers working together have amassed a volume of fact and principle which has not yet been completely codified and rendered accessible. An unexpectedly large proportion of the available rainfall has in many instances been obtained by successful drilling, in spite of the complication of the question by surface pollution, and in the face of many legal inanities and much charlatanry. And the extension of these methods to arid regions, as in Australia and North Africa, has brought under cultivation large areas which needed nothing but the " striking of the rock by the rod " of the driller to make new oases in the desert, and thus render available some of the richest soils in the world.

Much the same is true of overground supplies, which have been a blessing not merely to the towns and lands supplied, but to the rivers and drainage basins regularised and protected in large measure from ever-recurrent floods and the damage consequent upon them. Although in such works geological conditions are often taken into full account, an elaborate geological survey at a very early stage would in most cases more than pay its way. Such a survey would not only give a good preliminary idea of the nature and tectonics of the rocks underlying sites of dams and reservoirs, but it would save its cost in limiting the number and in giving rational direction to the inevitable pits which must be sunk, by restricting them to the elucidation of points which the surface mapping leaves obscure. It would at the same time direct attention to the innumerable pitfalls which sites often present and would generally provide on the spot much of the requisite material for construction.

It is an arguable question whether the expenditure of such vast sums as have been devoted to the supply of large towns is entirely justified. The provision of a single supply, of which large quantities are used for drinking, cooking, and industrial purposes, necessitates that the water shall be of immaculate purity, and this pure substance, the purest of all the things we consume, is employed—may we not say wasted—for flushing, washing, and a host of other purposes for which a less pure water would suffice. Surely the time has come when people could be educated up to the use of a dual supply, and this should be a commercial possibility where the area served and quantity used are really large. The experience of London has shown the very high cost of a single supply to all consumers and

for all purposes, and the limits of future supply are almost in sight. It seems to be time that the problems of a dual service should engage serious attention.

Power.—Owing to the configuration and rainfall of the British Isles, and their congested population, we are apt to think of water questions in terms of supply, and, though we are using a certain amount of water for power, there is only a limited development possible. In many other parts of the Empire, however, this is becoming a valuable asset, and nowhere more than in Canada, which is rapidly developing its resources on a very large scale. What has been said with reference to water-supply is of equal application here, for the physiographic conditions which bring about steep gradients accompanied by large bodies of water, introduce factors of denudation, transport, and deposition by the water which call for most careful selection of sites for reservoirs and works, if the all too frequent disasters are to be avoided, and if the schemes are not to be ephemeral in duration and excessively costly in upkeep.

With sources of power other than coal and water—including that of the tides—the geologist has little concern. But there has been brought into service at Volterra, in Italy, a new source of power in the high-temperature steam from fumaroles which had previously been used only as a source of borax. Now the steam is being tapped by borings adventurously carried out, and its chief heat is employed in running great power stations, only the residual heat being given up to the manufacture of borax. This may be but the beginning of the application of a new and valuable source of power in which the services of geology will be required and from which that science stands to learn much. We are haunted by the fear that a limit will be imposed by high temperature to deep mining, while that very heat may provide energy as valuable as the material which would otherwise be mined; just as we dread the gas from certain coal seams when the gas might, if it could be exploited, give a return equivalent to that of the coal itself.

Agriculture and Forestry.—Leaving aside relations already touched upon, the connexion of geology with agriculture and forestry is through the medium of soils and subsoils, and, though the geologist seems unsuited to deal unaided with soils, his methods are those which the soil investigator must use; and soil surveys are now being carried out by agriculturists working in conjunction with geologists. This results in giving new and valuable facts and inferences for the benefit of both sciences. On the geological side it is rendering more available the facts of plant distribution, and what has been called *agronomics*, which, speaking for myself, I have always found very hard to get hold of. On the other hand, the services of geologists are likely to be of especial value in the matter of transported soils, loams, loess, brick-earths, drifts, gravels, and the like, where the conditions of formation may in many cases provide a key to their peculiarities. The same considerations

apply to forestry, and here in addition well-established facts, such as the successive forest types displayed in peat-bogs, may betray principles that will be of service in practice. Questions of site, sewage disposal, and health are bound up with questions of water and agriculture and need no further notice here.

Military Science.—It will be readily admitted that geology has been of conspicuous service in connexion with military operations in such ways as the siting of camps, trenches, and dug-outs; while the minute study of the water-table in northern France during the late war was not only of value in obtaining water supplies but was of conspicuous utility in mining and counter-mining, in which exact and detailed knowledge was successfully pitted against a knowledge which was "just there or thereabouts".

The "eye for a country", the visualizing of features plotted on maps and making the utmost use of them, qualities on which good strategy is founded, are the same qualities which are essential to a competent geological surveyor; and I cannot help thinking that strategic ability would reap as much advantage from a knowledge of the underlying canons of topographic relief as the geologist would from a study of the principles of military topography. It was a wise scheme to train the British Home and Overseas armies on ground similar in kind and in relief to that on which they were about to fight in France; but it should have been realized that physical causes and the resultant topographical relief differ in essential particulars in temperate and tropical climates.

Intellectual Service.

Innumerable as are the services which the science of geology has rendered to man on the material side, these are at least equalled, if not outweighed, by those rendered on the intellectual side, either in the direct application of its principles to the life of mankind, or in the aid given to other sciences and the confidence engendered in such of their conclusions as can be tested in the light of geological history.

Throughout most of its range and in its more special directions, geology, like zoology and botany, is mainly an observational science. Multitudes of facts have to be observed and grouped, and as much skill is required in selecting from them the more significant and decisive as in collecting them. Experiment for the most part is of service in the criticism and verification of tentative theories; and, on the physical and applied sides more especially, it is becoming of great value. But the process of examination-in-chief, and the cross-examination in the field by a highly qualified and fully trained observer, are so exhaustive that not very much is left to submit for checking to the experimenter.

Even more than either of these two sciences is geology an open-air science and one which calls for and imparts a love of nature that cannot but deepen as knowledge increases. Its most interesting

work lies as a rule in the districts most attractive for other reasons. In the course of geological work the country must be thoroughly traversed, and, when possible, should be seen again and again, in all lights, under all aspects, and at all times and seasons. Hypotheses grow but slowly, and call for constant checking or verification in the field, the gradually growing ideas being an intensive spur in the collection of new facts or the re-observation of old ones, and in the comparison with like or unlike cases published or unpublished. But, as they grow, hypotheses give to their framer a power of prediction, more precise as the hypothesis is better founded; and one of the most fascinating parts of his work is the testing out of such predictions and the making of crucial observations thus needed and inspired. It is for these reasons principally that geology has earned its reputation as a fighting science. It is hard to decide just exactly when evidence amounts to absolute proof; and different observers, having reached varying stages in the completeness of their observations, may be led by the sum of them to different explanatory theories; or in the sphere of their own work they may be specially influenced by facts current there.

This seems to be the place to enter a protest against dominant ideas with regard to education and training in geology. The tendency in early education has been to squeeze out other sciences in favour of those that are called fundamental, and to suppose that, because it makes use of most other sciences, training in geology ought not to be begun until all others have been mastered. This is to go counter to the history of the science itself. Its leading methods were evolved in the early days of physics and chemistry and by men often ignorant even of such principles as were then understood. As geology has grown it has given to these sciences many problems for solution in return for the solutions received, problems which would have long waited for attention had not their geological application been urgent. Further, as the solution of his problems requires not only a very extensive knowledge but a workmanlike ability to apply both methods and principles, it is difficult to say at what stage even the most competent scientific man, if he is ultimately to deal with all his problems himself, can be ready to begin the study of geology.

Meantime, qualities of far higher value to a geologist, which in most cases can only be acquired young, are being lost, such as the habit of close observation, the aptitude to distinguish minute resemblances and differences, and the faculty of judging tendencies, together with the instinct and patience to make collections. These propensities come very early and speedily become blunted if not exercised. I would advocate, with all the earnestness of an old teacher, that some form of earth-knowledge involving observation of facts and collection of specimens, and the drawing of inferences from them, should find a place in schools and be encouraged at the Universities side by side with the fundamental sciences. Such

studies will not possess the meticulous exactitude of the others, but in this respect their tendency may be corrected by them. They will, however, bring the student into contact with realities, things as they are, instead of inaccessible, abstract conceptions, things beyond experience—such as *pure* substances, or forces acting in the absence of *friction*. They will give him the thrill of discovery and explanation, teach him that the end of science is to extract law and principle from observation and experiment, and, instead of keeping him along rigid lines to an assured and pre-obtained solution, will give him a choice of approach and accustom him to frame and test hypotheses which to him at any rate will be new and his own. Further, they will do much to teach him his own shortcomings and give him a keen incentive to acquire the very sciences which in themselves may be dull or even repulsive until he has convinced himself of their utility and necessity to his own work.

While acknowledging indebtedness to those sciences which have so generously contributed their results to geology, we feel that we have some ground for complaint that at times their votaries have not resisted the temptation to drop bombs which have exploded in our midst and produced a certain amount of trepidation and sometimes legitimate indignation. We consider that it is up to those who feel compelled to do this to acquire some knowledge of geological principles and of the lines of reasoning on which they are founded. They should recognize that a pyramid is difficult to upset, because in the process of building it the materials and structure have been carefully selected and tested by the builders. To be told after a century's search and reasoning that we must take our time-bill and " sit down quickly and write " off 80, or it may be 90, per cent of it, ought not to have disturbed us as much as it did, not more indeed than now does the permission of the representatives of the same science to multiply our original time-bill, if we like, by ten or twenty, or even more, so far as their present state of knowledge extends. Our answer is that we have not done the one and have no desire to do the other, so far as the sedimentary rocks at present known to us are concerned.

The geologist, however, should be, and is, the last to deprecate the application of the highest and newest conclusions of physical and chemical science to his own problems and to the criticism of his solutions of them, for it is certain that this will always result in doing much to reduce many of the barriers which retard his advance. For this reason we must welcome even so fantastic a hypothesis as that of Wegener, for the problem of the overthrust " nappes " of mountain regions is one of our greatest difficulties, and all explanations hitherto proposed are so hopelessly inadequate that we have sometimes felt compelled to doubt whether the facts really are as stated. But the phenomena have now been observed so carefully and in so many different districts that any real doubt as

to the facts is out of the question, and we must still look for some adequate method by which the overthrusting could have been brought about. And if dozens of square miles of ground have been shifted over their foundations and away from their roots for many linear miles in the course of a single geological Period, who shall say what might not be accomplished in the course of Eras ?

Important consequences flow from the fact that the goal and expression of most geological research is the construction of a map of the area studied. To the layman who studies a country with a geological map in hand, it is hard to resist the conclusion that the map is merely fanciful ; he can see no evidence for the lines laid down or the symbols employed, and he is astonished when trenching or drilling proves their correctness at any particular point. It is difficult for him to see or to realize the cumulative force of the aggregation of minute pieces of evidence, slight differences in slope or soil, variations in quality, quantity, or luxuriance of vegetation, variations in dryness or moisture, the distribution of culture, the extension into the area of some underlying tectonic plan—the laws of which may have been worked out elsewhere —and the thousand-and-one considerations which go to make up the mind of the geologist.

It is, of course, perfectly true that the individuality of the surveyor enters not a little into the extrapolation of geological lines beyond the points where direct observation of the rocks is possible. So much is this the case, that it is feasible, from the inspection of his map, to gauge, not only the geological competence, experience, and attainments of the surveyor, but his knowledge and grasp of physiographic form, his power to see into intricate solid geometry, his artistic skill of hand and eye, and, above all, that indefinable quality his " eye for a country " on which so very much depends.

The construction of a map has the further advantage that it grows by the alternation of periods of observation in the field with periods devoted to the thinking out of structure after each day's work and in the intervals between successive visits to the field, so that with every return to the ground, the facts may be re-observed and lines retested in the light of growing knowledge. It is true that ideal observation should be so complete and exact that re-observation has nothing to teach ; but, as a matter of fact, with a map as with a book, what one takes from it is what one brings to it, clarified, improved, and extended. There should be allowed to professional geological surveyors as much elasticity as possible, so that, in addition to detailed and exhaustive primary survey, there may be frequent revision in the light of their own work and that of their neighbours. In this respect the hand-coloured form in which geological maps were originally published has an advantage over the newer, cheaper, and more consistent colour-printed maps.

Geologists should give a cordial welcome to the new aid provided by aerial survey and photography. This provides the last point of view of their areas, which has been hitherto denied, though they have been in the habit of making use of the only substitute open to them, prospecting and photographing from the highest points accessible. Many unexpected results have thus been secured in archæology, and at least as much may be looked for in geological surveys even in settled and surveyed districts, while in unsurveyed and unprospected regions its use is proving of the highest importance. Too much credit cannot be given to Canada for its enterprise in using this method for the prospecting and preliminary survey of the animal, vegetable, and mineral resources of its great hinterland by means of the aeroplane. A great saving in time and cost has thus been secured, and the method bids fair to remove the reproach levelled at the British Empire that such vast areas of it are practically unknown.

Physiography and Geography.—It is because of the variety and intensity of observation essential to geological surveying—in the course of which every acre of his ground must be traversed, and much of it retraversed—that the geologist must necessarily become a physiographer and geographer. There is a limit to the perfection of topographic maps and surveys, even when, as in the United States, there is close co-operation between the Topographic and the Geological Surveys ; and it is the duty of the geologist to take note of innumerable features which have no delineation, still less explanation, on such maps. The geologist is probably the only class of person who has to traverse large areas with his eyes open, not to one class of phenomena only, but to all that can help him to decide questions of concealed structure ; and he naturally seeks to supplement this by personal contact with the inhabitants, and with their written and unwritten records, which it is part of his business to interpret and explain. Nor can he confine himself to the purely physiographic aspect of his area. He is led into bypaths as a by-play, and many facts with regard to the distribution of animals and plants, and of the dwellings, occupations, and characteristics of the people, can scarcely escape his observation ; neither can he shut his eyes to historic and pre-historic facts. Thus, when a geologist leaves his district, he is generally possessed of a store of knowledge reaching far beyond the strict bounds of his science.

While geologists, from the conditions under which they work, have been able personally to make individual contributions to these sciences, the most important service of geology as a whole has been the transformation of geography from a static into a dynamic science. In its earlier stages, geology discovered that progress involved the close study of the earth of the present and the application of that knowledge to explain its past changes ; and the progress of geology has only intensified both the need of deeper study and the fuller application of it. To-day it is essential for

geographers to be perfectly familiar with the past history of the earth in order that they may be able to explain the phenomena of the present.

The question may be summed up by saying that geology has become a physiological study of the earth as an organism with a life all its own. We can watch the geographical changes through which the earth has passed, revealed as they are in the nature and distribution of rocks and fossils. We can even discover the dry land—the actual landscape and physiographic relief itself—preserved in a fossil state, and judge from it the climates then prevailing and their distribution in distant epochs. We can form some idea of the modes or origin and dates of appearance of continents and mountain chains, and other leading features of the relief of the crust. We are learning to read the evidence given by the interactions of igneous and aqueous rocks as to the nature of the stresses by which the structure of the crust itself has been moulded. There are, it is true, many gaps in our knowledge, but their very existence is of value in quickening and directing research in order that our history may become as full as it can possibly be made. Each advance upon the technical side of the subject, the pursuit of detailed zonal stratigraphy, the application of the microscope in so many new directions, and the broadening of the area of study, all react sooner or later in improving, refining, and extending our knowledge of earth history. They combine with the evidence of palæontology to convince us that this earth of ours is still young, active, and full of life, and that any process of "running down" is constantly being held by self-acting checks which are putting forward to vastly distant ages "all prospect of an end".

Biological Sciences.—While astronomy has given us the conception of illimitable space, it has done much to destroy what has been called the anthropomorphic view of creation. Geology, on the other hand, has endowed us with an almost limitless conception of time, but it has done something to rehabilitate the importance of man as the highest product yet reached in the long history of the earth.

This it has done in the main through the intense reality that it has given to the conception of evolution. Although several authors, and two in particular, have pointed out that such a conception could not have been formed without the postulates of time and continuity of existence contributed by geology, it is hardly realized how much geological labour on the life of the earth, and on life on the earth, as summed up by Lyell and grouped and presented by him in his great work on "The Principles of Geology", was necessary to give to evolution a concrete and cogent application. The function of this labour could hardly be better indicated than by the position of geology as displayed in Lyell's earlier editions. The modern reader of them is continually haunted by the feeling

that the author was struggling for a single missing generalization which he failed to find; and although, in almost every branch of the subject treated, Lyell leads up again and again to the missing conception, and though the facts and inferences which he marshalled can now be seen to be marching on this great idea, he never quite succeeded in attaining it for himself. It was left for Darwin, than whom no one was more conscious of what he owed to Lyell, to see that the facts must rest on some great single fundamental principle, to realize that this principle was evolution, and to apply it to his own branch, the development of life.

Lyell had proved that the long history of the earth as recorded in the rocks revealed the operation of causes, small in relation to the earth as a whole, but persistent, the majority of them still in action. It was a further debt to Lyell that Darwin should bring in the continuous operation of small causes as the machinery operating and guiding the evolution of life.

But though the work of geologists, as summed up by Lyell, provided the starting-point for the conception of organic evolution, it did not stop here. The idea of Uniformitarianism in which that work culminated was meant as a reaction against the fantastic operations postulated by the Catastrophists, and was never intended to imply that these causes in the past were always balanced or distributed as they are now. There was in Lyell's statements nothing to indicate that denudation or earth-movement might not have been more active at periods of the past, that organic change might not accelerate or slow down, that there might not be variations in the trends of continental or oceanic development resulting in climatal and other changes, or that the very sources and intensities of energy from outside or inside the earth might not seriously vary. Only, warrant must be found for all such suppositions with regard to the earth of the past from fuller study of the earth of the present. And if we recognize the inner spirit which inspired the eloquent words of Lyell, when he had grasped that Darwin had supplied the one missing idea, we cannot fail to see that his Uniformitarianism included evolution as one of the "existing causes" to be taken into consideration.

The physiology of the earth, however, is that of a very complex organism, and we are sure that we do not yet know all the forces internal and external acting upon it, still less their relative value and intensity, their distribution and variation in the past, or the precise records which each is capable of imprinting on the rocks of the earth-crust. But it is becoming clearer that there has been a periodicity in the stages of development of the earth-crust, and that on these great pulses of earth life there have been imposed innumerable waves of smaller cycles; and that, on account of their interference with, or reinforcement of, one another, the simpler type of cyclic repetition which might have been looked for in the history is masked and broken and diversified by actual happenings

of an infinite variety. Van Hise more than once complained of the tendency of geologists to adhere to single explanations of events, and advocated the necessity of considering the co-operation of many causes; and it may well be that in many outstanding problems such as past glacial or tropical periods, coral reefs, stages of earth movement, progression and regression of the oceans, we may find the ultimate explanation in the interaction of a number of "true causes".

Frost Action in Superficial Deposits, Iceland.

By Leonard Hawkes, M.Sc., F.G.S., Reader in Geology, Bedford College, London.

(PLATE XXVII.)

THE object of this article is to draw attention to the patterns found in surface deposits of Iceland which are attributable to frost action and alternating frost and thaw, and to point out that such structures may be preserved in sediments, as valuable indicators of ancient climates.

The effects of frost action in superficial deposits have, in the last few years, attracted much notice, especially in Scandinavia, and the subject is ably surveyed in an important paper by Hogbom (1).[1] A useful account has recently been given by Huxley and Odell (2), with some additional observations from Spitsbergen.

The effects noticed in Iceland may be grouped as follows:—

(i) *Formation of a Network of Cracks in Clays.*

This has been noted by several observers (3, p. 259) (4). With severe frost, loud reports are heard from the ground, and mud flats are patterned by cracks, which may form a network similar to that resulting from the desiccation of mud.

(ii) *Growth of Knolls in Grassland.*

Areas of grassland in Iceland are often rumpled into a set of closely packed knolls known as "tuer"—illustrated in Plate XXVII, Fig. 1. These have been described by Thoroddsen (3, p. 262). They form the main obstacle to farming in Iceland, as no machines can be used on such land, although farmers have been known to remark upon the providence which has provided a greater area for grass to grow upon! At great labour some tracts have been levelled, but the knolls reappear in the course of some years.

(iii) *Formation of "Stone Rings" in Rocks which are being shattered by Frost Action.*

Rings of stones, "Karreboden," similar to those which have been described from Spitsbergen, have been reported from the Odadahraun (4). These are circular and elliptical areas of earth enclosed by borders of angular platey stones. Of similar character

[1] Numbers in parentheses refer to Bibliography at end of paper.

are the " rudemark ", in which clay is patterned by lines of angular stones marking out a set of irregular polygonal areas (3, p. 258). The structure I wish to draw attention to is less regular than that of the typical rudemark. Broken lines of angular stones are arranged in irregular rings, from one foot to a few feet in diameter, enclosing areas of clay, gravel, or smaller angular stones. This is very common in Eastern Iceland on level surfaces. The rings may be isolated single ones. They are so irregular as to escape general observation, until one has been recognized. During my first three visits to Iceland I saw none, but after noting the first one they have been obvious everywhere.

(iv) *Formation of Stone Rings in Unevenly Graded Deposits.*

This type has not previously been described from Iceland. It consists of a regular patterning of gravel flats into five- to six-sided areas, the outlines of which are made by the larger pebbles. The enclosed areas are occupied by smaller stones. The structure was first noted on the flat-topped bank of gravel in the Lon district of South-East Iceland, representing an ancient " sand " bar belonging to the raised beach. The arrangement was seen at many places, and always in raised beach deposits, especially west of Eydalir, Breiddal, west of Sydri-Firdi, Lon, and north-east of Svinafell, Lon (Plate XXVII, Fig. 2). The polygons are 1 foot in diameter. The larger stones of the boundaries average 1 inch across, those in the centre $\frac{1}{4}$ inch. Beneath the thin covering of stones in the centre is clay and fine gravel. The pattern is repeated over considerable areas and persists to a depth of 3 to 4 inches, below which all is homogeneous. The arrangement is sometimes preserved under a thick moss growth, as in a series of raised beaches between Sydri and Nedri Firdi, Lon. On gentle inclinations solifluction has elongated the areas in the direction of slope, and on steep banks the larger stones are arranged in parallel lines, also in the direction of slope.

(v) *Formation of Shallow Hollows in Gravel.*

When exploring the gravel of the " bar " which stretches across the bay of Lon, I noted that at Hvalsnes, where the bār abuts on the mainland, the gravel a few feet above high tide was pitted with a great number of closely packed, even-sized hollows, with narrow ridges between, as if many horses had been stamping about there. The pebbles were flat, and averaged $\frac{1}{2}$ to $\frac{3}{4}$ inch in diameter, the depth of the hollows 2 to $2\frac{1}{2}$ inches, and their diameter 12 inches. The stones are evenly sized to show sorting. Some sand is present at a depth of 3 inches.

The phenomena recently described from the raised beaches of the South Waigat Islands (2, p. 227) resembles that noted as iv. Here there is sometimes no sorting of stones, the regular patterns being marked out by up-ended tabular fragments.

Origin.

For a general discussion reference may be made to the papers already cited, some few points only are here noted :—

Type No. i is due to contraction produced by hard frost. It was noted by Spethmann to have occurred after a night temperature of — 10° C. The action was studied experimentally by freezing a mud layer in a beaker. At a temperature of — 15° C. a network of fissures was formed, a temperature of — 2° to — 3° C. produced no such effect.

Types ii *to* v are found under the conditions of repeated frost and thaw action, and result from the operation of different forces from those of contraction responsible for Type i. The irregular rings (iii) are formed during the breaking up of rock material. Some were seen to be derived from one block—which had rolled down a scree slope and travelled beyond the scree.

Types iv *and* v are formed in material which is already heterogeneous, without concomitant shattering and here the process is one of sorting only. They have only been discovered in raised beaches, which leads to a suspicion that they might have an entirely different origin, but their essential similarity to other types, and the fact that they only occur in beach material which is now beyond the reach of the waves, is reassuring. The pattern is as regular as that resulting from the contraction of igneous rocks and muds, and must be due to a force exerted equally in all directions in the deposits as a whole.

Type v is being developed a few feet above high tide, and no temperatures will be met with here much below freezing point. Icelanders are aware that in heterogeneous deposits the larger stones have come to the surface and have noted that the same effect would be produced by shaking up a mixture of variously sized fragments. This is a pertinent observation and the large pebbles have probably come to the top as the result of a slow, imperceptible, long-continued shaking of the upper layers, produced by the formation and melting of ice crystals in them, with its consequent raising and lowering of particles. The occurrence of the pitted gravels seems to throw some light upon the sorting which is evidenced horizontally. The upward movement has been greatest at the ridges, and in unevenly graded material the larger stones would in time come to predominate here. The origin of the ridges is probably related to the expansion of the deposit, consequent upon the formation of ice in it. The subjection of suitable mixtures to alternate frost and thaw in the laboratory may throw light on this problem.

Evidences of Ancient Cold Climates.

The powers of adaptation of organisms to varying conditions may be so considerable that the geologist must welcome climatic indicators of an inorganic character as surer ground upon which

to base conclusions regarding palæo-climates than that of fossil evidence. The relationship between climate and terrestrial deposits has been discussed by Barrell (5). The recognition of cold climates of past geological ages has, up to the present, been almost solely based on the evidence afforded by tillites, which, as has been pointed out (6, p. 176) is inadequate, and of limited value. Glaciers do not necessarily form in cold regions, and glacial drift may be laid down under mild climatic conditions. Other evidences of frost action and glacial erosion which have been used are the occurrence of screes, freshness of felspars in clastic rocks, and presence of scattered stones in fine sediments. These evidences are seldom convincing, and are often capable of interpretations which are independent of a cold climate.

Leffingwell describes features of deposits from North Alaska which are ascribed to frost action, e.g. gravel mounds, cavities left on the melting of wedges of ground ice, and suggests that these might persist in districts which now have a milder climate, as evidence of Arctic conditions in recent geological times (6, p. 177). Those gravel deposits of Southern England which were laid down in front of the ice sheet might be expected to show structures similar to those illustrated in Plate XXVII, Fig. 2, and the rubble-drift the more irregular sorting of Type iii. They have not yet been noted; but Mr. G. Slater has reported the occurrence of groupings of stones in the boulder clays of East Anglia which have tentatively been referred to as stone polygons (2, p. 223).

It occurred to the writer that the structures described from Iceland might be covered by, and preserved beneath, later deposits, and that they might occur in the rocks of the stratigraphical column as indicators of ancient climates. All, excepting Type i, would be certain evidences of a cold climate, as these structures are not known to form excepting under Arctic conditions. The possibility of mud cracks being due to frost action must not be lost sight of when reading the record of the rocks (7, p. 526).

The occurrence of stone groupings would provide more satisfactory evidence than that of tillites, as they cannot be transported, and therefore indicate the former existence of a cold climate where they are found. They will be evidence of a continental deposit as they cannot form beneath the sea, as has been the case with some tillites. They are not to be expected as a feature of boulder clays, as they cannot form beneath the ice sheet, but only on its retreat with the exposure of the upper surface to sub-aerial weathering.

One possible example of a " fossil " frost pattern is that described from the Triassic tillite deposits of Central Africa. Ball and Shaler write :—

" The distribution of the boulders and pebbles is patchy, areas 2 to 40 feet across being without pebbles, while between are heavy conglomeratic areas " (8, p. 691).

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FROST ACTION IN SUPERFICIAL DEPOSITS, S.E. ICELAND.

FIG. 1.—Grassland, Breiddal.

FIG. 2.—Raised-Beach Gravels, Lon.

To face p. 513.]

It is suggested that a look-out be kept for these structures in coarse and irregularly graded deposits. The irregular arrangement of Type iii is not easy to detect, and needs a trained and watchful eye. Exposures of bedding-plane surfaces are the most favourable. The regular patterning of Type iv may be expected to provide a valuable criterion for distinguishing normal torrential deposits from those of glacial outwash fans.

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EXPLANATION OF PLATE XXVII.

FIG. 1.—"Tuer" at Eydalir, Breiddal, S.E. Iceland. In the background basalt cliffs rise above the raised-beach plain, which is bare of vegetation in the distance, but is covered with knolls elsewhere, except for the levelled potato patch.

FIG. 2.—Sorted gravels of the raised-beach "bar" west of Vik, Lon, S.E. Iceland.

On a Quartz-porphyry from the Lake District.

By SIDNEY MELMORE, B.Sc., F.G.S.

A SMALL quarry was opened about three years ago at Thwaite Head, which lies between the southern ends of Coniston Lake and Windermere. It is on the west side of the road between that hamlet and Hawkshead, and exposes a nearly vertical sill, 40 feet wide, running E.N.E.-W.S.W. in the Bannisdale slates. On the south side a series of joint-planes running parallel to the bedding of the slates and curving inwards at the top have split the igneous rock into flags, while in the body of the rock the jointing is much coarser, so that it is quarried in large blocks. Both the igneous rock and the slates are much decomposed and friable along the southern junction, and it is here a little galena is said to have been found when the quarry was first opened. This is not improbable, as the old Thwaite Head lead mine is situated not far off on the banks of Dale Park Beck.

In the hand-specimen the rock has a greyish-pink colour and is made up of pink felspars about a millimetre in size, sometimes showing simple twinning; also opaque white spots and smaller

particles of a ferro-magnesian mineral in a greyish-pink ground-mass. It has a specific gravity of 2·64.

Under the microscope the rock exhibits a holocrystalline porphyritic structure with phenocrysts of quartz, orthoclase, plagioclase, and a ferro-magnesian mineral. Quartz is seen to occur principally in small rounded grains about 0·25 mm. in diameter, but occasionally they reach 1 mm. in size, and a large rounded bipyramidal crystal 1·3 mm. in length with short prism faces also has been noted. This, and some of the larger grains, contain liquid inclusions with bubbles. Acicular crystals (rutile) have also been observed in the quartz.

Plagioclase, often in stout idiomorphic crystals, with refractive index lower than that of balsam, is abundant. Albite twinning is common, the crystals generally being divided into wide lamellæ and occasionally they show pericline twinning in addition. The multiple character of the twinning can sometimes be made out in ordinary light, alternate lamellæ having a more dusty appearance than others. One or two zoned crystals have been noticed. Symmetrical sections generally give extinction angles of about 16°, but vary from straight extinction up to 24°. Their range in composition is thus from oligoclase to andesine. Orthoclase occurs as Carlsbad twins, and one Baveno twin has been noticed. Quartz is sometimes ophitically included in it. The larger felspars, $\frac{1}{2}$ to 1 mm. in width and up to 2 mm. in length, are often broken across in one or more places, the cracks being filled with the material of the ground-mass. Frequently the felspars, when in the position of extinction, show a speckled appearance, as if they were continuous with the ground-mass, and flakes of muscovite can be seen in them occasionally.

The ferro-magnesian constituent is a bright blue-green mineral with a platy structure; it is pleochroic, the absorption colour in longitudinal sections being blue-green for vibrations parallel to the length of the section and straw-yellow for the direction at right angles. It gives low interference colours and thus has the properties of chlorite. Sections are compensated with the quartz wedge perpendicular to the length of the fibres. One slide examined showed a perfectly shaped six-sided section having angles of 125° and 117° occupied by chlorite, so that it is clear we have this mineral pseudomorphous after hornblende. The chlorite is so arranged as to give straight extinction with respect to the trace of *m* (110) of the hornblende. A longitudinal section of a similar pseudomorph showed faces inclined at an angle of 73°. These pseudomorphs are sometimes partially enclosed by a felspar phenocryst.

The ground-mass consists of grains about 0·03 mm. in diameter, principally of felspar with a little quartz and occasional wisps of chlorite. Little crystals of apatite are fairly frequent constituents, and this appears to be the only accessory mineral with the exception of pyrites which can be seen as small specks in some hand-specimens.

A few irregularly shaped patches of exceedingly fine-grained felsitic matter also occur.

Thus, the rock possesses all the features of a quartz-porphyry, though large phenocrysts of quartz are not so abundant as those of felspar. The presence of the idiomorphic pseudomorphs of chlorite after hornblende is perhaps the most interesting feature. Comparing this with other rocks in the district, hornblende has been noted by Dr. R. H. Rastall in the Wastwater granophyre, but "much of it shows uralitic character" (*Quart. Jour. Geol. Soc.*, vol. lxii, 1906, p. 266), and Dr. A. R. Dwerryhouse has observed "a pale-green pleochroic amphibole" in the granitoid rock at Stainton Mill Dam, and pseudomorphs after pyroxene or amphibole in the dykes on Yewbarrow and High Fell (ibid., vol. lxv, 1909, p. 63).

REVIEWS.

A Long Life's Work: An Autobiography. By Sir Archibald Geikie, O.M., K.C.B. pp. xii + 426, with 2 portraits. London: Macmillan and Co., Ltd. 1924. Price 18*s*. net.

FOR half a century Sir Archibald Geikie has been the most conspicuous figure in British Geology, and during his forty-four years' tenure of the office of Director-General of the Geological Survey, he was naturally regarded in this country and abroad as, in a sense, the leader and official spokesman in geological science.

Sir Walter Scott had been dead but three years when Sir Archibald was born, and no railways then existed in Scotland. In his early Edinburgh days he knew Hugh Miller and David Forbes; he was a contemporary of Lyell and Scrope, and worked with Murchison and Ramsay. He has been intimate with all the great men of his time in the world of foreign geology; he has witnessed the birth and growth of most of the Geological Surveys abroad. Among his many offices and appointments, omitting those in foreign countries, he has been twice President of the Geological Society, President of the British Association, and Secretary and President of the Royal Society, and for two generations he has taken a leading part in the scientific and literary life of the metropolis.

It is natural, therefore, that we should turn to the autobiography of such a man with lively interest, expecting to hear a first-hand account of the ways and doings of our geological forebears, and of the origin and growth of the many geological problems that vexed them, and in which he himself played a part.

The first two chapters deal with his childhood and early education at the High School and University, and the reader gets fascinating glimpses of Edinburgh life as it was in the first half of last century. Few cities in the world were more likely in those days to foster a love of field geology than the Scottish capital. Its rocky volcanic heights, and the mountains, glens, and firths of the surrounding country invited the eager curiosity and study of the young geologist.

Was it not, too, the home of Hutton and Playfair, and the battle-ground of the great Neptunist controversy of the previous generation?

In the first few pages we get a delightful picture of the author's first visit to the Highlands when a lad ten years old, sketched in that vivid and picturesque language which has made him famous, and which was used to such good purpose in his *Scenery of Scotland*. The study of the volcanic rocks of Arthur's Seat and the Pentlands, and later those of Arran and Skye, was his early geological love. It moulded his scientific thought and directed his researches. Henceforward, the volcanic history of Britain became the keynote of his geological work, to which he has returned again and again during his long career.

As it was Hugh Miller's *Old Red Sandstone* which gave to the young Geikie the greatest impulse to his scientific studies, and the model upon which he based his early style of geological essay-writing; so it was Murchison who did more than anyone else to launch the young man on his career.

When he had been but five years on the Geological Survey, he was suddenly called off to the Highlands, from his mapping in Fife and East Lothian, to accompany his Chief on that memorable excursion in 1860, so well described in his *Life of Murchison*. From the standpoint of worldly advancement, this event was probably the most fortunate, as it was the most fruitful in Sir Archibald's life. Few men have had a more generous patron than the brilliant and masterful Chief, who dominated the geological world of that day. And the young assistant must have proved of great service, with his ready pen and clever sketches among the geological complexities of rugged crags and mountain tracts, while the chief, then in his 68th year kept, perforce, to the more open and easier paths. Perhaps, too, this friendship, amounting almost to hero-worship on the part of the younger man, was more momentous in helping to shape his official attitude when in later years the assistant became head of the Geological Survey. It certainly did much to complicate the issue, and postpone a final settlement of the great Highland Problem, which is referred to in Chapter VII of this autobiography.

As we read through the chapters of this book we are impressed by the author's incessant industry, and the fixed determination to use every available hour, and every means to the furtherance of work which he planned to do. He possessed the faculty, developed quite early in his career, of describing the results of his field observations in language at once clear, terse, and often most interesting and picturesque. And this at a time when there was precious little geological literature untainted by the grotesque exaggerations and errors of the catastrophists. What Huxley did for Darwin, Geikie has largely done for Lyell.

Isolated papers and magazine essays were brought together and reprinted in book form, and an ever-widening circle of readers was brought within the ambit of his pen. His early textbooks, including

the little primer on Physical Geography—perhaps the best thing he ever wrote—were written at a time when natural science was beginning to be seriously taught in the schools. No British geologist has been so prolific or so successful as a biographer. Small wonder that his prestige and fame in the geological world grew apace, and especially abroad.

Making due allowance for such an extended period of high public service as that of Sir Archibald Geikie, few scientific men, and certainly no geologist in this country, have occupied so many important posts, and been the recipient of so many honours and distinctions. No British geologist has been more in touch with foreign scientific work or counted so many foreigners among his friends and acquaintances. His long and distinguished public service alone could not have done this. In large measure it has been due to the excellence of his textbooks, and the volume, clarity, and style of his geological writing.

This book is packed with personal anecdote and choice character-sketches of the author's contemporaries, and the geologist of to-day and of the future will turn with relish to the apt descriptions of many a famous man of a past generation who has helped to make geological history. Many, too, are the generous appreciations of his intimate friends. But is there not some risk in appraising in cold print the virtues and shortcomings of friends who are still with us, as in the case of two of the author's most eminent and faithful colleagues (see pp. 243–5) ? The citation of the supposed comparative failings of the one is perhaps overstepping the bounds of good taste.

It is characteristic of the man that in the evening of his life, and in the leisure of his retirement, he has returned with enthusiasm to his early love of the classics. The frequent sprinkling of quotations from his favourite Latin authors throughout this book serves to remind the reader of the fact.

When we turn to the pages of the book dealing with the progress of geological science, wherein the author has taken part, we are met at times with some disappointment and surprise. Thus, in the account of the detailed mapping by the Survey of the North-West Highlands, the reader is apt to get a biassed impression of the history of this memorable controversy. What is less excusable, he is unfair to some of his famous contemporaries, now no longer with us, who played a great part in that geological drama. Few geologists to-day conversant with the facts could be misled by it ; but it is otherwise with the non-scientific reader, for whom also the book is avowedly written.

In the account of the solution of the problem of the North-West Highlands in Chapter VII, no mention is made of Nicol's early discovery of the key to the stratigraphical succession ; there is no reference to the work of Lapworth, or to that of Callaway, Hicks, and Bonney. One feels considerable sympathy for Peach and Horne, who are inferentially made solely responsible for pricking the Murchison bubble.

Having selected these two eminent geologists for the important and difficult task, the author says, " They were instructed to get at the truth, regardless of anything that had been published on the subject." One almost wonders whether, in the absence of such explicit instructions from their chief, these brilliant geologists were thought to be capable of distorting or evading the results of their field-mapping. The reader who is not forearmed with knowledge of the true history of these discoveries, is left with the impression that the Survey were solely responsible for the correct interpretation of the structure " that nature had so cunningly concealed ". As the author admits, " no one could have definitely proved it by a mere cursory examination of the ground," which was what Murchison attempted to do. But the key to the structure had been already discovered by careful and patient observation and field-mapping, notably by Nicol and Lapworth, when Peach and Horne commenced their work.

We recognize that his zeal for the reputation of the Geological Survey may have caused him to pass over the work of Nicol, Lapworth, and others ; but in a book which will be quoted as containing an authoritative account of the progress of geological discovery in this country, such partiality of treatment cannot be passed by without notice. It is true that in a footnote the author refers to the Geological Survey Memoir, wherein full references to all the observers are given, but the general reader is not likely to consult this.

Again, in referring to the completion of the fine Survey Memoir on the Silurian rocks of Scotland, published in 1899, just before the Director-General's retirement, and of which he expresses pride and satisfaction in having taken a hand in the planning and completion, it was surely a strange omission to allude to the brilliant work of its authors, Peach, Horne, and Teall, without one word of reference to Lapworth, whose pioneer work on the Graptolites, and whose detailed mapping of the Moffat and Girvan areas made the work of Peach and Horne then possible.

The same sense of justice is offended when the reader, familiar with the history of research among the volcanic rocks of Scotland, so frequently referred to by the author, seeks in vain for a mention of the labours of Judd, or the work of Harker in Skye, the most complete, detailed and fruitful investigation of a volcanic region ever accomplished in this country.

But, after all, perhaps we are over-stressing such omissions. It may be that we ought not to expect the author to set forth the progress of geological science in such a work as this with any pretence to completeness, or even strict impartiality. Is it not the work of an old man telling the tale of his life by his own fireside, as he says on the first page of the book, and naturally lingering over the events in his life most pleasing to recall, and talking of the people who have been his close friends, and for whom he has felt the greatest sympathy ?

This would be, perhaps, the safer and kindlier view to take. At any rate, the curious blanks in the narrative already noted can scarcely be due to want of space. Several pages are devoted to the author's handling of the late Duke of Argyll and his supposed find of fossils in the Highland Schists. The poor Duke was scarcely a scientific man, and certainly no match for the keen-witted and experienced geologist with whom he chose to argue his case, and who, if need be, had the expert palaeontologists of the Survey to support him.

On the whole, we would rather believe that these blemishes in so absorbing and readable a book were not wilful and calculated. It would be sad, indeed, to reflect that a man so eminent and full of honours, in the quiet evening of his days, and so long separated from the heat and dust of controversy, was unable, or unwilling, to give the world an impartial account of these old scientific controversies in which he played his part, and to do full justice to his departed adversaries and fellow-workers in the science.

There is a tinge of sadness in the closing pages of the book, inevitably brought about by family bereavement.

An Appendix contains a short sketch of the life of the author's only son, Roderick, who died so tragically in 1910, together with an eloquent and touching eulogium written by the Headmaster of Harrow School.

The work is excellently arranged, with a copious index, and contains two striking portraits of the author, one with his little grandson, taken at Haslemere in 1923.

W. S. B.

THE VESUVIUS ERUPTION OF 1906: STUDY OF A VOLCANIC CYCLE. By F. A. PERRETT. 151 pp., 24 plates and frontispiece, 98 figures. Carnegie Institute of Washington: Publication No. 339. 1924.

THIS is a remarkably detailed account of the great eruption of Vesuvius in April, 1906, from the able pen of Mr. F. A. Perrett, who has had unexampled opportunities of long-continued observation, and who is an expert vulcanological physicist. He relates the preludal events from 1903 to April, 1906, and the subsequent events down to 1921, both being necessary for the proper understanding of the great paroxysm of April 4–8, 1906. The work is cast into the form of a narrative, followed by numerous critical and elucidatory appendices dealing with every main feature of the eruption. Many of the observations so minutely detailed in this splendid monograph will be of value to petrologists in the study of the problems of igneous rock genesis.

Perrett emphasizes the cyclical nature of Vesuvian eruptions. There is an accumulation of energy in the long repose period, and its paroxysmal release in the eruptive periods. Thus, there was a gradual rise of the lava column prior to the 1906 eruption. The

three factors favourable to the initiation of a major eruptive phase are (1) great height of the lava column, and consequently great pressure on the walls of the vent; (2) maintenance of the liquid lava at a high temperature by active gas conduction and reaction, with resulting fluxing power; (3) Restriction of vent at the top to a tiny conelet on the crater rim, with resulting increase and accumulation of gas tension downwards in the lava column.

The actual eruption is divided by Perrett into three phases which he calls respectively, the initial luminous lava phase, the intermediate gas phase, and the final dark ash phase. The second of these phases is not accepted by many vulcanologists who have described the eruption; but Perrett insists on its individuality as a continuous powerful emission of gas, like a boiler "blowing off", but with comparatively little ejected solid or liquid material. This uprush lasted for many hours and produced a column of vapour 11 km. high, with a wonderful cauliflower summit cloud.

The main eruptive element, according to Perrett, is gas; and (although he does not actually say it) he gives the impression that lava and ash are to be regarded merely as incidental and secondary phenomena in volcanic eruption. The actual mechanism of eruption is as follows:—In the upper part of the vent a gas-charged magma accumulates, exothermally reactive, with the evolution of great heat. There is a free escape of gas to the air, and consequently little explosive activity. Lower down, however, the conditions are practically equivalent to those of a closed conduit, and a highly gas-charged, potentially explosive magma develops. Eruption occurs when some factor disturbs the state of equilibrium thus obtaining. This factor is frequently found, as in the case of the 1906 eruption, in the lateral splitting of the volcanic cone, and the discharge of sufficient of the upper layers of liquid to release explosively the powerfully gas-charged magma below. The fissuring of the south wall of the cone on 4th April thus "pulled the trigger" of the eruption.

An expansion of the magma occurs concomitantly with its uprise in the conduit, and the condition of energy release passes gradually downwards once the eruption is initiated. The emission of lava and the destruction of the terminal cone forms the first phase of the eruption; the intermediate phase of gas emission represents the coming into action of the lowermost and most heavily gas-charged layers; the final low pressure, ash-laden phase is associated with approaching exhaustion and the infall of the remains of the cone.

Perrett goes on to describe the fluent lava and the solid ejectamenta; the explosive, seismic, and electrical effects; the hot avalanches of volcanic sand at high temperature; and the subsequent degradation and collapse of the crater. He believes there is a gradual transition between extreme forms of "aa" and "paehoehoe" types of lava, and hints at a regular subdivision

on this range somewhat on the lines of the Rossi-Forel scale for earthquakes. From lateral fissures on the flanks of the cone the lava was delivered along more or less horizontal tunnels; and there was no accumulation of material nor any attempt at cone building around the vents. Hence, there occurred here a miniature type of fissure eruption.

Of great interest to petrologists is the actual observation of re-fusion of old lava. Perrett was "standing with a group of students upon the hard lava surface of the cone when this gradually increased in temperature until the heat underfoot was unbearable. On moving away it was observed that a round area 2 meters in diameter was becoming incandescent in full daylight, and this began to swell upward until, without a fracture, the material reached the point of complete fusion, and a small ephemeral lava stream started flowing down the slope. There was no explosive emission of gas, the fusion resulting directly from superheated lava beneath the surface". Within the crater a superheated stream of lava melted for itself a depressed channel in the older floor. Owing to the uniformity of material at Vesuvius, the assimilation that has undoubtedly taken place has not resulted in any differences of composition.

This finely produced and printed quarto memoir is magnificently illustrated with 24 full plates, and 98 text figures of excellent quality, mostly taken from Perrett's own photographs. It is a rich mine of vulcanological facts and theory.

G. W. T.

REPORT OF THE COMMITTEE ON SEDIMENTATION. By W. H. TWENHOFEL, Chairman, and Members of the Committee. pp. 65. Issued in mimeograph form by the National Research Council, Washington, D.C. 1924. Price $1.

THE first half of this publication consists of reports on the present position of instruction and research on sedimentation in the universities and scientific institutions of the United States and Canada, giving evidence of considerable activity in this subject. A specially interesting report by Professor W. A. Tarr describes the great importance attached to the study of the petrography of sediments by the oil companies, many of whom possess laboratories of their own adapted for this form of research, which has thrown much light on the special problems of oil-geology The remaining 32 pages include several brief memoirs and notes on various points on which work has recently been carried out, with some account of methods. Special attention may be directed to a paper by R. W. Sayles on the progress recently made in studies of seasonal deposition in glacial sediments, with reference chiefly to the work of Berkey, Antevs, and Sauramo on varve clays in America and Finland, with a useful bibliography. E. M. Kindle shows in another report that lamination and colour-banding can be produced in sedi-

ment settling under uniform conditions, the chief controlling agent being temperature. T. Wayland Vaughan discusses the present state of studies on the precipitation of calcium carbonate in sea-water, confirming the bacterial action suggested by G. H. Drew in the Florida region. G. D. Louderback gives an account of investigations in San Francisco Bay on the relation of marine organisms to the physical character of the bottom deposits, and a short paper on soil colloids and sedimentation will be of interest to agriculturists. Finally, the Chairman reports that the treatise on sedimentation undertaken some years ago by a group of writers is in an advanced stage of preparation and may be published in about a year's time or a little later.

GEOLOGICAL SURVEY OF NYASALAND: The Mineral Resources of Nyasaland. Pamph. No. 1. By F. DIXEY, Government Geologist. pp. 1–8.

AS the title denotes, the greater part of this paper is devoted to the occurrence and distribution in the Protectorate of minerals and rocks of economic importance, of which, including water, no less than twenty-three are given. The geological part is taken very largely, often almost word for word, from the account of the country by Andrew and Bailey, published in 1910. Dr. Dixey, however, makes an addition (which may prove temporary) to the list of Central African geological formations, viz. the Dwangwa Series, later than the Karroo System, and consisting of "gently-tilted sandstones, mudstones, and calcareous beds" overlying sandstones and conglomerates.

J. P.

SOUTHERN RHODESIA: "The Geology of the Country west of Sinoia, Lomagundi District." By H. B. MAUFE, B. LIGHTFOOT, and the late A. J. C. MOLYNEUX. Geol. Sur. Bull. No. 9, 1923. pp. 74, coloured Geol. map, 1 : 119,000, plates i–xiii.

SINOIA, the principal town in the area of about 700 sq. miles included in the Report, which is a sequel to the preliminary work by Molyneux (Bull. No. 6) and bears the same title, is situated 82 miles N.W. from Salisbury in northern Mashonaland. After a detailed description of the Geology, including a large proportion of petrography, sections on "Mineral Deposits" and the "Sinoia Caves" (illustrated by three plates) follow, and a Bibliography and an Index conclude a very complete and important piece of work. Practically no alteration is made in the classification of the Lomagundi System, and the Nyaneti fault separating the two limbs of the syncline which these rocks build is mapped as extending north and south across the area, a distance of nearly 40 miles; the uppermost group, the Piriwiri Series, lying to the west.

In regard to the Basement Schists, the Eldorado Conglomerate

Series is now ranked as the youngest member, divided from the underlying Quartz-sericite–schists, Greenstone schists and Ironstones by an unconformity. The Conglomerate Series is much altered, for the " main folding and metamorphism " of the Basement Schists took place after its deposition. It is perhaps about these rocks that the interest of the Report centres. Their upper limit is not yet known, but the Series is considered to have a " thickness of many thousands of feet." A considerable amount of discussion has taken place concerning the nature of the basal conglomerate, but the sedimentary origin of the rock appears now to be fully established. The matrix and interbedded rocks are described as " biotite-chlorite schist ", " calc-chlorite schist ", " calcareous felspathic grit ", and the like.

The plates include two of photomicrographs and sections of the ore shoots of the Eldorado mine, the Golden Kopje, and the Union Jack, the conglomerate being the ore rock in the first instance (the gold is in the matrix), banded ironstone in the two others.

J. P.

Some Cornish Veinstones. By E. H. Davison. *Mining Magazine*, Vol. XXXI, pp. 15–17. 1924.

In this note are described some very instructive specimens of Cornish veinstones found by the author during the reorganization of the Hunt Museum at Redruth. They include tin veins in granite, copper veins in granite, copper veins in slate, wolfram veinstones, and some miscellaneous types. Many of the specimens are illustrated by excellent photographs. The general results agree with those already arrived at by the author and Dr. Cronshaw, and confirm the zonal arrangement of the minerals in the lodes as noted by several authors, especially by Collins and MacAlister. As there has been of late a good deal of discussion as to the order of arrival of minerals in veins, the author's conclusions may be of some interest. He finds the order to be as follows: (1) quartz; (2) cassiterite; (3) tourmaline, chlorite; (4) wolfram; (5) chalcopyrite, mispickel; (6) pyrite; (7) blende, quartz, fluor; (8) chalybite, galena (?). The occurrence of quartz in two or more generations is a common phenomenon, which is in need of some physico-chemical explanation.

REPORTS AND PROCEEDINGS.

Edinburgh Geological Society.

19*th March*, 1924.—Mr. David Balsillie, B.Sc., F.G.S., F.R.S.E., President, in the chair.

1. " A Glacial Overflow Channel near Grieston, Peeblesshire." By R. J. A. Eckford and W. Manson.

This overflow channel breaches a subsidiary ridge that divides the drainage of the River Tweed and the Violet or Orchard Burn

Valley. It commences near the 950 feet contour and continues down the hillside as a well-defined channel for three-quarters of a mile towards the Tweed. The main part of the waters that carved this channel came from a temporary lake that was formed by the glacier holding up the higher drainage in the Orchard Burn Valley.

The formation of these glacial overflow channels in the Tweed seems to mark an extended pause in the retreat of the valley glaciers.

2. "Note on the Discovery of *Edmondia punctatella* (Jones) in Fife." By D. Haldane, B.Sc.

This fossil was found last year on the foreshore at Culross and at bores at Saline, in West Fife. It occurs abundantly in a thin bed of inferior oil-shale underlying the Calmy Limestone, and above the Jenny Pate (Hirst) Coal. First recorded in 1865 at Dalry, Ayrshire, and at Thornliebank, Renfrewshire, Professor T. R. Jones described this curious fossil as *Estheria punctatella*, but in 1890 he amended his first classification and named it *Posidonomya punctatella*. Later, however, Dr. W. Hind named it *Edmondia punctatella* (Jones), but considers that there is still doubt on account of the absence of positive details of the interior of the shell.

Since this fossil was first noted, as the result of boring operations, our information regarding its occurrence has greatly increased, and now we have a continuous record along the outcrops of the Calmy Limestone on the north-west, west, and south-west of the basin of the Central Coalfield of Scotland. It is a curious fact, however, that *Edmondia punctatella* is definitely known to be absent on the east of the coalfield. The strata at Culross are the northward extension of the eastern outcrops of the Calmy Limestone, and yet *Edmondia punctatella* is abundant.

3. "The Correlation of Chemistry and Geology." By J. Adam Watson, A.C.G.I., F.I.C.

From an historical point of view the story of the earth can be told in terms of Stratigraphical Geology and Palaeontology. By their aid it is possible to draw maps which will show fairly accurately the distribution of land and sea at any geological period. When, however, investigations are pushed into the reasons for, and the causes of the various forms of igneous rocks, it is necessary to enlist the services of Chemistry. Broadly stated, the problem becomes one of determining the exact conditions that will cause a magma of definite composition to crystallize into a certain assemblage of minerals. The data which are required in order to do this are gradually being accumulated, and in the end it may be hoped that sufficient accurate and detailed information will be acquired to formulate a concise and probable theory that will embrace all types of igneous rocks. Regarding both sedimentary and metamorphic rocks the same kind of problem becomes evident. Thus, it seems probable that the ultimate complete understanding of all the manifestations of geology will only be attained when the chemical

problems involved in their production have been carefully investigated. On this account it is evident that Geology must look to the sister science of Chemistry for assistance in unravelling the history of our planet.

4. "A Monchiquite Dyke in Lauderdale." By Dr. F. Walker, B.A.

On the left bank of the Earnscleugh Burn, one mile due south of Earnscleugh Farm, a dyke of N.E. trend cuts the Upper Old Red grits of Lauderdale. This dyke is a monchiquite, and contains large phenocrysts of biotite and hornblende, measuring up to one inch across. The rock is petrographically distinct from all other monchiquites described from the east of Scotland, but has affinities with the monchiquites of Patna and Colonsay. It is probably of Carboniferous age.

16*th April*, 1924.

1. "Peléan Eruptions." By Dr. J. S. Flett, F.R.S.

The great eruption which destroyed the city of St. Pierre in 1902 and caused the death of 30,000 persons belonged to a type which up to that time had not been recognized by geologists. Although the amount of lava discharged was small, the eruption was excessively violent, as all the lava took the form of fine cindery ashes, which descended the mountain as an avalanche of red-hot incandescent dust, overturning and destroying everything in its path. The almost simultaneous eruption of St. Vincent was of the same type though less spectacular in its features. Geologists had tried to identify this type of eruption among the ancient and extinct volcanoes, but for a variety of reasons no very conclusive results had been obtained. Still it was possible that in the Azores, the Andes, Java, and Japan, Peléan eruptions had taken place in the past, and might occur again in the future. In 1912, however, a great eruption broke out in the uninhabited parts of Alaska, from a mountain known as Katmai, and careful exploration by American scientists during several years has proved that all the features of the eruption of the Soufrière in St. Vincent had then been reproduced on a far larger scale. The reports showed that the great valleys had been filled with sheets of red-hot dust, and from fissures in this mass steam was constantly ascending. The distinctive features of the three great eruptions of this class were discussed, and the suggestion was made that an explanation was to be found in the history and properties of the volcanic magma, and the gases dissolved in it, which by their violent expansion shatter the liquid rock into a cloud of minute particles.

CORRESPONDENCE.

THE SPECIES CONCEPT IN PALAEONTOLOGY: AN ANALOGY.

SIR,—In his lucid and stimulating remarks on the species concept in your August issue, Dr. Trueman accurately reflects the trends of palaeontological thought. For some time past palaeontologists have come to see how their supposed lineages are really composite and may be more properly regarded as series whose terms have been appropriately culled from bundles of parallel lineages. These lineages are parallel in that the different characters of the organisms comprising them have evolved along similar lines, though in its evolution, each character was largely independent of others, and its rate of evolution was fast in this lineage and slow or even stationary in that.

Dr. Trueman now claims that any such bundle has many anastomoses caused by the free interbreeding of the forms constituting it, so that we must now think of a plexus of freely interbreeding forms rather than a bundle of parallel lineages, but a plexus showing a general progress along definite lines. That is to say, a transverse section " low down " in such a plexus will show a predominance of forms in an early stage of evolution, while a section " higher up " will show a large percentage of advanced forms. The particular instance that Dr. Trueman has in mind is that of the Hettangian and lowest Sinemurian oysters.

Having in mind this instance and others, such as the Senonian Polyzoan *Pelmatopora*, I would suggest that the free interbreeding was confined to the earlier stages of evolution, and that the system, though at first a plexus, soon became straightened out into a bundle of parallel lineages. Indeed, Dr. Trueman hints at such a view when he speaks of " broader limits of infertility ".

An excellent illustration of such a system confronted me while I was reading Dr. Trueman's paper in my garden—an analogy that may be worth handing on to your readers. In a circular flower-bed about 2 ft. in diameter, plants of *Ipomaea purpurea* were climbing sixteen parallel strings. If each plant represents a lineage, then the whole system corresponds to a bundle of parallel lineages, and the ontogeny of each plant to the phylogeny of a lineage. Moreover, as each plant is followed from the bottom to the top of its string, its characters are seen to change ; for instance, the petioles shorten, the internodes lengthen, and the number of flowers in each inflorescence increases ; so that a transverse section of the system at 5 ft. from the ground will show later stages of ontogenetic development than one at 6 inches or a foot from the ground. But a given transverse section will also show that the plants on all sixteen strings are not at the same stage of development, and that even in the ontogeny of a single plant some characters have developed faster than others ; for instance, at the height of four feet the internodes of one plant may be decidedly longer than those of another. More-

over, the heights of the several plants are different, though all were sown at the same time. Differences in the comparative rates of ontogeny of the individuals and in the rates and degrees of development of the different characters are generally ascribed either to differences of environment or to "individual variation", i.e. to causes inherent in the individual which may be unknown or partly known, such as differences in gametic composition. The differences of individual environment of the plants under consideration must be very slight and no more than those of the different members of parallel lineages found where they grew and died together in the same geological bed; and the differences of rate and degree in the development of their ontogenetic characters is probably mainly due to individual variation. Similarly the differences of rate and degree exhibited by the trends of parallel lineages are probably due in a large measure to "individual variation" of the lineages, i.e. to causes inherent in the individual lineages. But here our analogy fails; for the ontogeny of an individual is largely a recapitulation of ancestral, and at least a repetition of parental, characters, while the evolution of a lineage is a march along new lines.

Again, if the relation of a species to its genus is similar to that of the individual to its species, then, to be logical, we must name our bundle of parallel lineages as a genus, and each lineage as a species; the arbitrary points on a lineage, which we have been accustomed to name as species, or as mutations in Waagen's sense, must be termed merely phylogenetic stages in the life-history of a species; and the nodes of Dr. Trueman's supposed plexus must be described as hybrids. Without advocating or deprecating such a course, I would simply moot its desirability.

New species may be regarded as arising either as hybrids at the nodes near the base of the plexus, or as new offshoots from a persistent radical. This supposed basal plexus is represented in the illustration just given by the chance crossings and wanderings of the stems before they find the string up which they ultimately climbed. Suppose that, when such crossing stems touched, they could fuse and produce at that point a hybrid shoot, this would illustrate the origin of a new species produced as above suggested.

W. D. Lang.

Chelsea.
16th August, 1924.

TYPE-SPECIMENS.

Sir,—The Governing Body of the Imperial College of Science and Technology having decided that it is undesirable to retain type-specimens of fossils in a palaeontological collection used for teaching purposes, it may be of interest to record the transfer of the very few specimens concerned to the several museums chosen as most appropriate in each case.

1. To the British Museum (Natural History)—holotype of